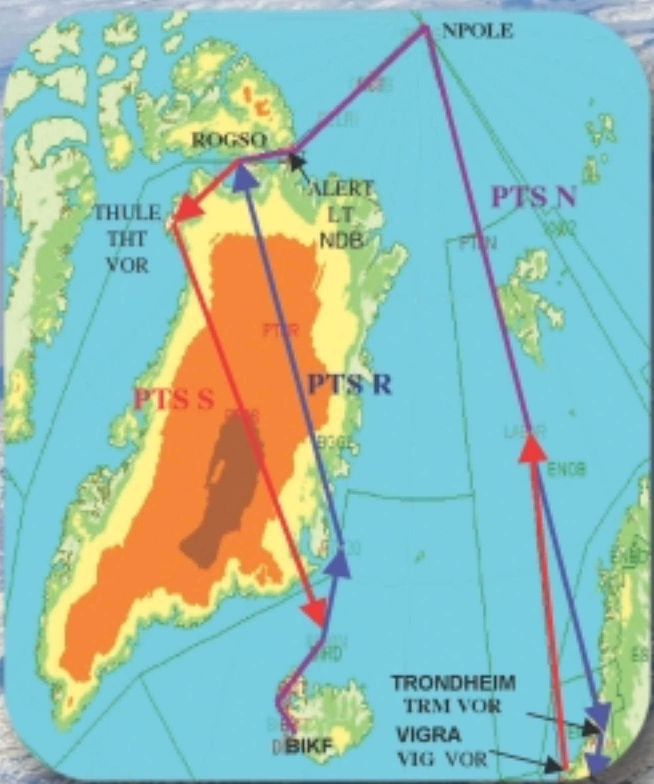
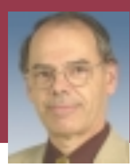
A340-500 Arctic flights

Two flights exceeding 10 hours each were required for the A340-500 fuel system certification and for the evaluation of the ADIRS performance. In addition, the behaviour of the navigation system and the Electronic Instrument System (EIS) had to be checked in the polar area including flying over the North Pole itself.

Both flights were planned and operated by the Airbus Flight Test Division: Toulouse-Keflavik and Keflavik-Toulouse, each time via the North Pole.

This article recalls some aspects of the polar navigation observed during these flights.





Capt. **Michel Brandt**
Airbus Test Pilot
Flight Operations Support

On TRUE heading

We left Toulouse on 12 September 2002 with 12 people on board, maximum fuel uplift and full flight-test equipment, including ballast, which gave a take-off-weight (TOW) of 325,000kg. Our flight plan led us to Vigra VHF Omnidirectional Range (VOR) in Norway to intercept the Polar Track System (PTS) route "November". This route follows the meridian 10°E to the North Pole.

Although Magnetic Heading (MH) is available until 82°N at this longitude, we selected TRUE heading reference as soon as we were established on the PTS. With this selection, the indications on navigation display (ND) *(Figure 1 below)* and Multipurpose Control and Display Unit (MCDU) were in line with the True Tracks (TT) given on our navigation charts.

Although the Flight Management and Guidance System (FMGS) remained in GPS PRIMARY mode of navigation update all the time, we were able to cross-check the FMGS navigation with the Automatic Direction Finder (ADF) sometimes at a very great distance, up to 500 nautical miles (nm) from the Non-Directional Beacon (NDB). However, the wave propagation may not be always as good, for example, during periods of aurora borealis.

Flying in NAVigation autopilot (NAV) mode, nothing significant happened until approaching the North Pole. We observed the relative position of each Inertial Reference System (IRS) to anticipate the system behaviour while flying over the North Pole.

DIGRESSION ON MAGNETIC HEADING

Traditionally, the polar area was defined as an area of magnetic compass uncertainty and the limit was sometimes set where the earth magnetic field is less than 6 microtesla. Except for the standby compass, modern aircraft no longer have magnetic sensors "slaving" the gyro-compass to the magnetic north. The magnetic variation is extracted from tables in the Air Data/Inertial Reference System (ADIRS) and the Flight Management System (FMS). These tables give an accurate magnetic variation up to a latitude of 82° N, or 73° N in function of the longitude. Beyond this latitude TRUE reference must be used. Consequently, the 6 microtesla limit has no meaning for these navigation systems. We nevertheless observed during these flights that the standby compass indication was coherent well above the charted 6 microtesla limit.

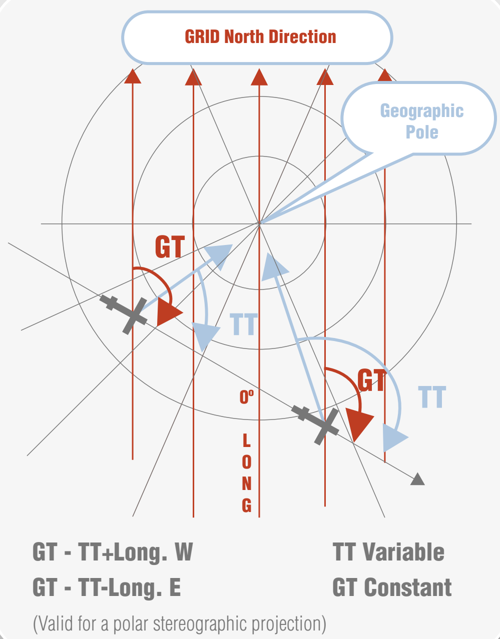
When passing 65°N latitude the grid track (GT) appeared on the navigation display.

Figure 1

DIGRESSION ON GRID TRACK

When flying east to west or west to east at very high latitude on an orthodromic (great circle) route, the true track changes quite rapidly due to the convergence of the meridians. On older aircraft, the true heading was not directly available to the crew. "Old style" Horizontal Situation Indicators (HSI) were set in a so-called free gyro mode on the Grid North reference. The characteristic of the grid track is that it remains constant on an orthodromic route as indicated in the drawing below, right.

With our modern navigation system, the grid track would not be mandatory, as the true track is always available and the navigation charts indicate the outbound and inbound true tracks at each waypoint for cross-check. But the grid track indication on the navigation display provides the crew with at least a convenient stable indication for navigation monitoring in this moving display environment.



Note: Where words are spelt in capital letters it refers to their use as cockpit labels, messages and displays.

Figure 2

Note: The TAXI CAMERA was selected "on" in flight so the flight test engineers could see the landscape from their station in the cabin.

Figure 3a

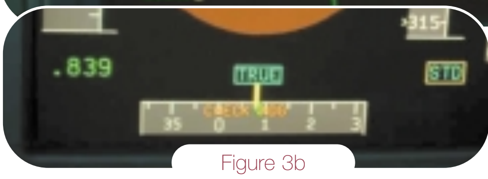


Figure 3b

HEADING BEHAVIOUR

At about 20nm before the Pole the heading discrepancies on ND became noticeable and finally triggered, as expected, the HDG DISCREPANCY Electronic Centralised Aircraft Monitor (ECAM) caution *(Figure 2)* and CHECK HDG on the ND and Primary Flight Display (PFD) (Figures 3a and 3b).

The heading discrepancy is due to the fact that each IRS has a different position relative to the Pole.

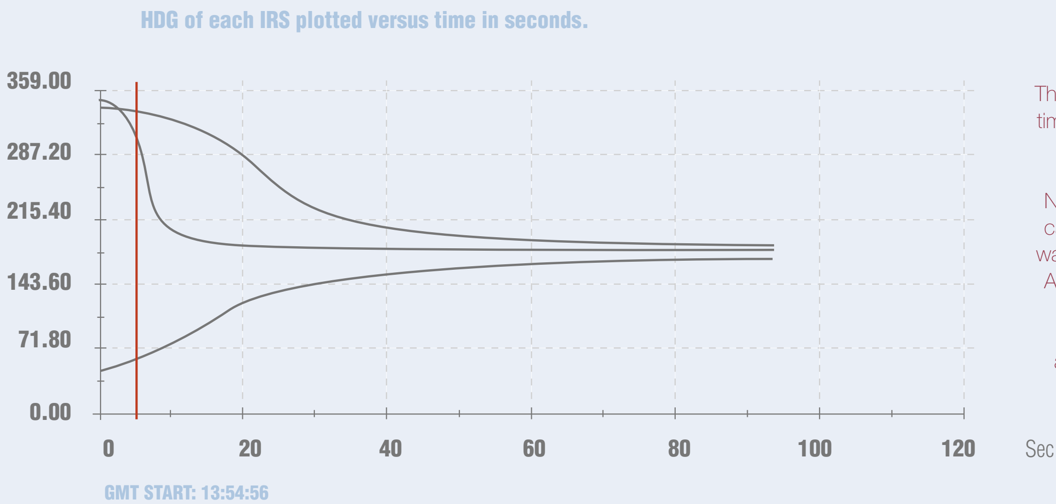
The ECAM procedure cannot be followed, as all heading indications start to move very quickly and switching ATT HDG on IRS3 would not help. The autopilot remained engaged in NAV mode and the aircraft continued nicely straight ahead.

When flying exactly (with GPS accuracy) over the North Pole the ND display swung over by one hundred eighty degrees from a True Heading (TH) close to 000° to a TH close to 180° (the drift was small). But very quickly all headings were again in agreement as shown on the flight test traces given in *Figure 4* (below), and the ECAM caution disappeared.

At 20nm outbound from the North Pole, everything was nominal and it was time for us to turn left to intercept "another" 180° course to the VOR of Thule (THT).

Despite the magnetic variation of 66°W at Thule, the VOR THT is magnetically oriented (some VORs in north Canada are oriented to the geographic North). As we were flying with TRUE reference, the VOR needle on ND in MAP mode or ROSE NAV mode is automatically corrected with the magnetic variation, so as to get a TRUE bearing. Otherwise the needle would not indicate the direction to THT. This is marked by the magenta color of the needle and the label CORR next

Figure 4



The red line indicates the time of the flight over the North Pole.
Before reaching the North Pole the heading calculated by each IRS was close to 360°/000°.
After passing the North Pole all headings converged rapidly to approximately 180°."

Figure 5

Figure 6

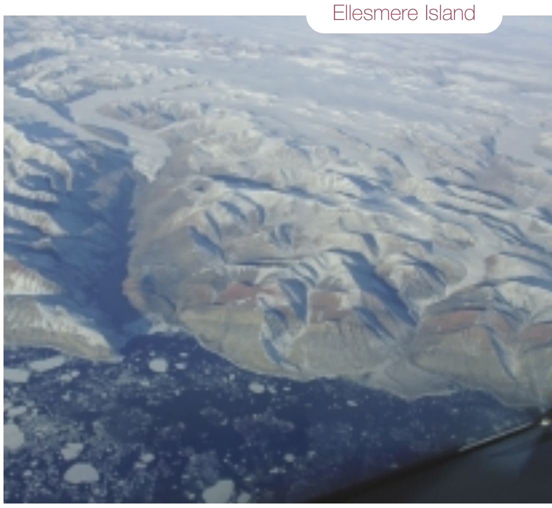
to the VOR2 display as shown in *Figures 5 and 6*. The indications of the Digital Distance and Radio Magnetic Indicator (DDRMI) and the ND in ROSE VOR mode are not corrected, as they would be on a conventional aircraft. When we were at 77nm to THT, the DDRMI needle of VOR2 (not shown here) was pointing towards 255° magnetic instead of 184° True as shown in *Figure 5*.

After passing THT *(Figure 6)* the outbound true track to the 7440N waypoint was 095°. On this leg the true track changed significantly, from 095° to 123° due to the convergence of the meridians, but the grid track remained conveniently constant and equal to 163°.

Leaving the oceanic airspace we deselected TRUE to revert to magnetic reference and continued to destination, arriving at Keflavik after 10 hours 45 minutes flight time, having enough fuel to return to Toulouse with more than the required reserves.

The next day we left Keflavik for Toulouse and headed north east to join and follow the PTS route "Romeo" up to ROGSO, a waypoint located 230nm to the north of Thule. At this waypoint we turned right to the North Pole. On PTS "Romeo" we selected TRUE reference, as it is better for navigation monitoring; but this time, before crossing 82°N, we deselected TRUE to revert to magnetic reference in order to see how the ECAM will advise us to select the right heading reference.

Ellesmere Island



Flight test engineers at station

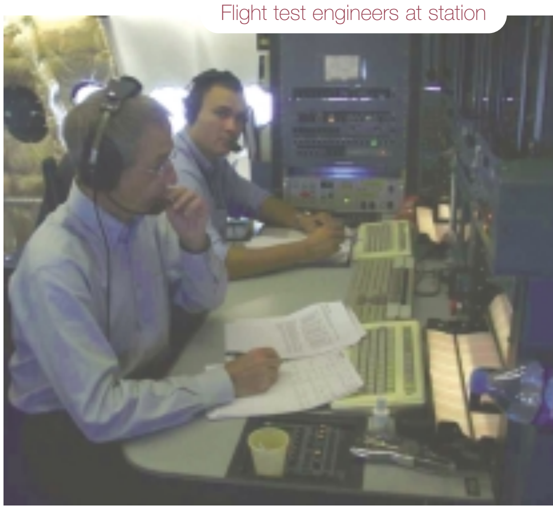


Figure 7

Figure 8

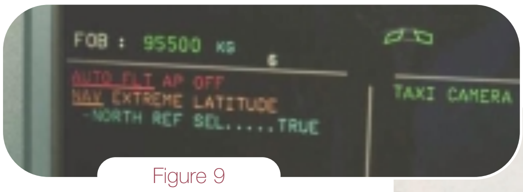


Figure 9

As shown on *Figure 7,* we were on a magnetic track of 090° on course to Alert NDB (identification code LT) corresponding to a true track of 025°, giving a magnetic variation of 65°W.

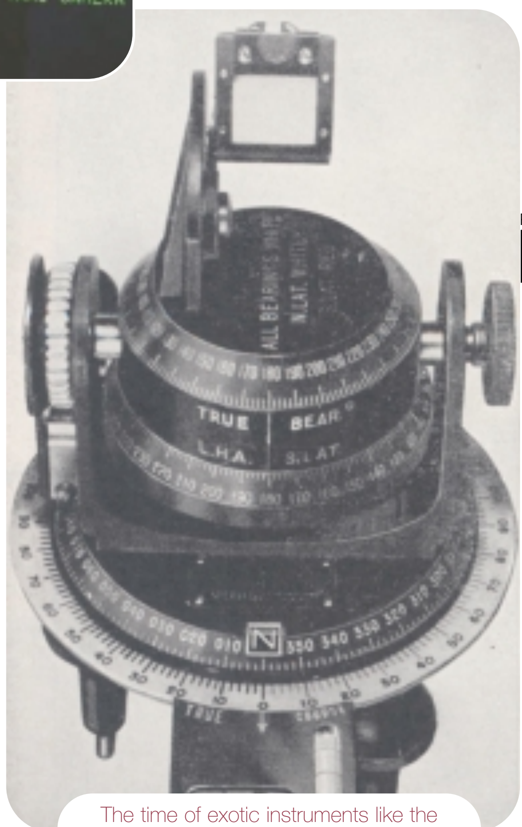
When we reached 82°N, we got the amber message SELECT TRUE REF on ND *(Figure 7)* and on MCDU *(Figure 8).*

Intentionally we did not follow this instruction, waiting for the next step, the ECAM caution at 82°30' N. At this latitude, the IRSs switched automatically to TRUE reference, which triggered the EXTREME LATITUDE ECAM amber caution *(Figure 9).*

The autopilot went off as well, because each IRS crosses the latitude limit at slightly different times. We performed the ECAM procedure, confirming the TRUE reference selection and re-engaged the autopilot.

For the purpose of the test, we decided to fly nearby the North Pole this time with autopilot in HDG mode. As the North Pole was a turning point, to join the PTS "November" route southward we passed abeam it by about 10nm. This distance was sufficient to limit the heading discrepancy, so that we were able to steer the aircraft with sufficient accuracy. The recommended procedure is to fly with the autopilot in NAV mode, but in a situation where the BACK UP NAV would have to be used, this test confirmed that flying in HDG is easy, even close to the North Pole.

We continued heading south on PTS "November" until Trondheim VOR in Norway. Leaving the oceanic area, we resumed normal navigation and landed in Toulouse after 10 hours flight time.



The time of exotic instruments like the astrocompass illustrated here is gone.

Conclusion

With the polar navigation capability of the Airbus Long Range family of aircraft using the flight management system, polar flights are no longer different from standard navigation.

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